From Fermi Arcs to the Nodal Metal

Scientific Achievement

The pseudogap phase in the cuprates is a most unusual state of matter: it is a metal, but its Fermi surface is broken up into disconnected segments known as Fermi arcs. Using angle resolved photoemission spectroscopy, we measure the temperature and doping dependence of the pseudogap in momentum space. We find that the resulting Fermi arcs depend only on the ratio $T/T^*(x)$, where $T^*(x)$ is the temperature below which the pseudogap first develops at a given hole doping x. In particular, the arcs collapse linearly with T/T^* and extrapolate to zero extent as T goes to zero. This suggests that the $T = 0$ pseudogap state is a nodal liquid, a strange metallic state whose gapless excitations are located only at points in momentum space, just as in a *d*-wave superconductor..

Significance

It is widely believed that understanding the pseudogap phase, which lies between the Mott insulating and the superconducting phases in the cuprates, is the key to understanding high temperature superconductivity in the cuprates. Our results on the scaling of the pseudogap with $T/T^*(x)$ give completely new insight on how this mysterious state of matter evolves with temperature and doping and present a challenge to existing theories. This scaling points to the ground state of the pseudogap being a the nodal liquid, a strange metallic state whose gapless excitations are located only at points in momentum space, just as in a *d*-wave superconductor. This suggests that there are no competing order parameters at low temperatures, and that the superconductor evolves from this state with increasing temperature by developing coherence. Performers

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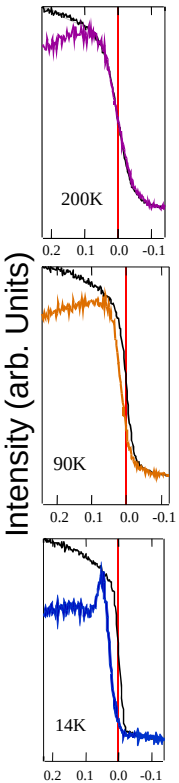
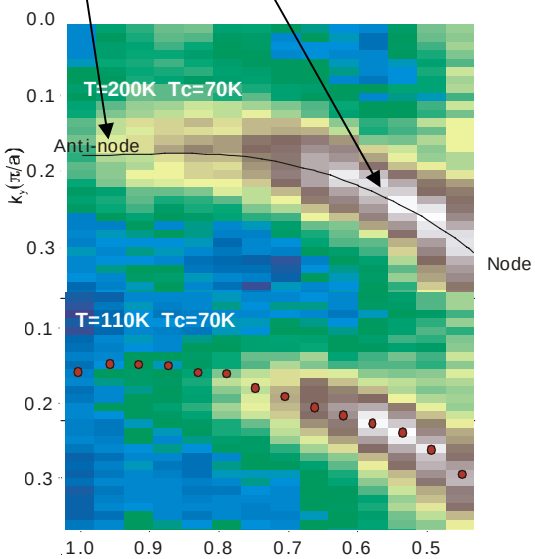


The normal state: At high *T*, the normal state is strange. There are no coherent excitations, only collective excitations.

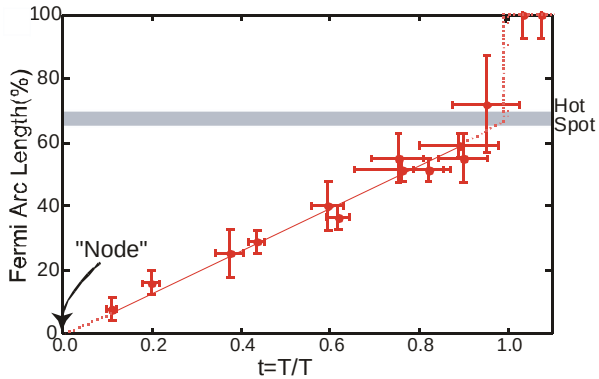
The pseudogap: As the *T* is lowered, a gap appears long before superconductivity.

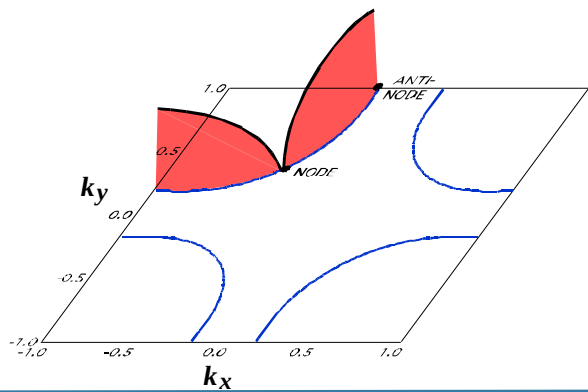
Superconducting state: exhibits a gap, and sharp peaks due to coherent excitations.

The Fermi arcs: a most unusual state of matter: it is a metal, but its Fermi surface is broken up into gapped and ungapped segments (Fermi arcs), which change with *T.*



Scaling of the Fermi arc length vs reduced temperature $t = T/T^*(x)$





The ground state of the pseudogap is a “nodal metal”
A strange metallic state with only 4 gapless points.
Can think of SC = PG + phase coherence

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